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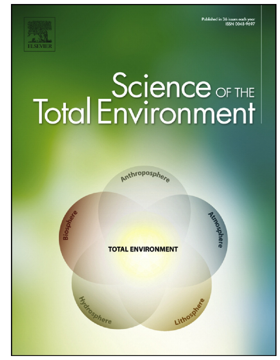

Prospects and challenges of concentrated solar photovoltaics and enhanced geothermal energy technologies

Tabbi Wilberforce, A. Baroutaji, Zaki El Hassan, J. Thompson, Bassel Soudan, A.G. Olabi

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– Prospects and challenges of Concentrated Solar Photovoltaics and Enhanced Geothermal Energy Technologies

Tabbi Wilberforce[1], *A. Baroutaji*[2], *Zaki El Hassan*[1], *J. Thompson*[1], *Bassel Soudan*[3], *A.G. Olabi*[3,4]

1. Institute of Engineering and Energy Technologies, University of the West of Scotland, UK
2. School of Engineering, Faculty of Science and Engineering, University of Wolverhampton, UK.
3. Dept. of Sustainable and Renewable Energy Engineering, University of Sharjah, P.O. Box 27272, Sharjah, UAE.
4. Mechanical Engineering and Design, Aston University, School of Engineering and Applied Science, Aston Triangle, Birmingham, B4 7ET, UK.

Abstract

Reducing the total emissions of energy generation systems is a pragmatic approach for limiting the environmental pollution and associated climate change problems. Socio economic activities in the 21st century is highly determined by the energy generation mediums, particularly the renewable resources, across the world. Therefore, a thorough investigation into the technologies used in harnessing these energy generation mediums should contribute to their further advancement. Concentrated Solar Photovoltaics (CSP) and Enhanced Geothermal Energy (EGE) are considered as emerging renewable energy technologies with high potential to be used as suitable replacements for fossil products (petroleum, coal, natural gas etc). Despite the accelerated developments in these technologies, they are still facing many challenges in terms of cost. This review paper presents a detailed background about these renewable energy technologies and their main types such as solar tower, parabolic trough, and so on. Also, the principle challenges impeding the advancement of these energy technologies into commercialisation are discussed. Possible solutions for the main challenges are presented and the future prospects for such energy generation mediums are reported.

Keywords: Renewable energy, Concentrated Solar Photovoltaics, Enhanced Geothermal energy, Fossil fuel, Technologies

1. Introduction

The demand for cost-effective modern energy sources has increased in the recent years due to the rapid increase in the population across the world. Renewable energy sources are considered the future of the energy industry. This is mainly because they are very abundant and environmentally friendly compared to fossil products [1]. The advancement of renewable energy as the sole medium for energy generation in the world faces major setbacks despite their attractive advantages over the traditional fossil-fuel ones [2-4]. The major challenges are related to the high initial capital cost needed in the execution of most renewable energy projects and the underdeveloped technologies for harnessing the energy for some renewable sources.. Such challenges hamper the advancement of most renewable sources into full commercialization [5-7]. Today different types of renewable sources are springing up like the enhanced geo thermal, concentrated solar photovoltaics, ocean energy etc. These types of energy are developed from existing energy sources like biomass, solar, hydropower and wind [8]. The emerging types of renewable energy (Fig. 1) are ecofriendly and abundant to meet the world energy demand [9]. The focus of the current review paper is on some of these emerging technologies, their prospects as well as setbacks impeding their advancement into full commercialization [10].

2. Renewable energy sources

The world has seen a paradigm shift in renewable energy between 2004 – 2017 [11-13]. The rapid rise of renewables clearly shows the prospects of these viable energy generation mediums hence are currently competing with the traditional power generation medium. The contribution of renewable energy in the field of energy supply varies by country and region due to different geographic distribution of manufacturing, usage and export. From the report of the GSR– 2016, Brazil, Canada and USA remain the countries for non – hydrogen installations. Jamaica, Morroco, Uruguay, Honduras and Mauritania invested huge amount of money into sustainable power and fuels. The renewable energy generation capacity and capacity change as a percentage of global power is shown in Fig. 2 [14,15]. Over the last eight years there has been a zigzag behavior from the graph but appreciable increase for power obtained from renewable sources.

The performance of renewable energy in terms of investment has seen high rise in the last decade as well [16]. The capital cost for the establishment of wind turbines and solar photovoltaics has reduced in the last few decades as well. In the year 2015, nearly 103GW of renewable energy capacity was established. Large hydropower that was established during this period was not factored into the 103GW power capacity recorded [17]. Wind and solar were the dominant source of renewable energy in 2014 with their supply capacity reaching 49GW and 46GW respectively but in the year 2013, only 32GW of energy was generated from wind while solar supplied 40GW to meet the world’s energy demand [18]. In 2014, the International Energy Agency (IEA) published the price of electricity produced by renewable energy sources [19]. A comparison between the USA energy generation prices and the residential end – use in 2014 was clearly presented. Hydropower was observed to be very competitive when compared with the other types of renewable energy generation mediums. The main setback of the hydropower was the difficulty in finding a suitable location to install such energy plant. Other renewable energy sources such as geothermal and onshore wind were reported to have equally reached grid parity. Renewable energy sources continue to be recognized in the research community as the future of energy generation as shown in Fig. 3.

Today, solar PVs are dominating the renewable energy sector due to their high plausibility compared to other types of renewable energy, as shown in Fig. 4. The graph vividly shows that renewable energy sources have higher potential when compared to traditional supply of energy. In 2013, the International Renewable Energy Agency (IRENA) developed a map called the remap for the future of renewable energy until 2016. The agency using reports from 40 countries based on their national plans has also been reported as a reference case. Table 1 is presented as having information for 2013/2014. Renewable energy technology is often subdivided into emerging energy technology (EET) and mainstream energy technology (MET). Main stream sources for sustainable energy are hydro power, solar, etc [20 – 25] while the emerging technologies include marine, CSP etc [26 – 29].The last decade has also seen the springing up of some new energy technology which has been thoroughly researched as well. This new emerging technology has either been commercialized but in the early stage of commercialization or still under commercialization.

3. The Concentrated Solar Photovoltaics (CSP)

The Concentrated Solar Photovoltaic Technology (CSP), as shown in Fig 5, is the medium where electricity is generated by directing solar rays to a small point. This technology operates using mirrors and lenses to direct the rays from the sun to a receiver where there is a thermal energy carrier (Oil, water, molten salt etc.) that functions as a primary fluid in the CSP circuit that absorbs the heat. With the aid of a turbine these heats generated can be used directly or sent to a secondary circuit to produce electricity [30]. During unfavorable weather conditions, such as very cloudy, concentrated solar PVs can still generate electricity as they have storage system to store parts the generated heat to continually generate electricity when the sun goes down. Concentrated solar PVs have good capacity factor compared to the other energy generation mediums such as wind and traditional PVs due to the storage system attached to it. Developing a proper storage system is of particular importance for designing an effective CSP energy plant [31 – 33]. Heat energy is generated with the help of the solar collector that absorbs the radiations from the sun. With the help of a heat transfer fluid, the heat energy generated is transferred via the collector [33 – 36]. The heat transfer fluid performs a role as the link between the power generation system and the collector.

There are four main types (Parabolic trough, Linear freshnel reflectors, Parabolic dish collector and Solar towers) of concentrated solar photovoltaic and each of the type is dependent on the technology used to absorb the solar radiation, the way the sun's radiation is directed towards Concentrated solar PVs (FT) and how the sun's rays are received (RT). Each of these types are clearly shown in Fig. 6.

CSP need more solar radiation to meet the minimum threshold to generate the required power. They operate predominantly well in hot climates and dry weather conditions. Therefore, CSPs are suitable for some places around the globe such as South Africa, North Africa, Australia and the Middle East.

The Parabolic Trough (PT) technology is currently the commonly used type of CSP. However, it still undergoing significant developments. The parabolic trough technology is the older idea used by researchers compared to the other types and there is reduced risk during its development compared to the others. The initial cost used in the establishment of a solar tower and Fresnel systems is expected to be reduced significantly in the next few years due to high research being conducted in the area with the sole aim of enhancing its performance at reduced cost. California was the first location for the establishment of a concentrated solar plant with no thermal storage between 1984 and 1991. Due to the high dependency of fossil fuels which was very cheap, there was a break after the discovery of the CSP technology but in the early 2000s researchers revised the concept all over again after oil prices started becoming unstable and unreliable. The current leading stakeholders for the concentrated solar PVs technology are America and Spain. The total CSP as shown in Fig. 7 installed around the whole world in 2012 was 2GW but 15-20GW CSP project were being planned commence predominantly in the United states and Spain [35]. Due to the high rate of research geared towards this useful technology, many investigations have been conducted relating to the types of solar collectors, structures and even the storage as well as the electricity conversion systems have all been researched thoroughly [36-40].

All CSPs have a backup system which allow regular production and to maintain appropriate level of certainty with the expected capacity. The backup system is usually powered by fuel. A fuel burner supplies the energy to the heat transfer fluids. Fossil fuels, biogas and solar energy can be used in place of the fuel burner. The cost of operating the CSP would have increased exponentially if the plant relied solely on solar fields. The backups help CSP to also gain from relying on grids significantly. Due to smaller losses, the thermal storage technologies for CSP are highly efficient compared to other energy storage devices. It is possible for on demand energy to be generated through the application of CSP technology [42 – 45]. The 2050 projections of power generation using CSP for different regions around the world is shown in Fig.8. Fig. 9 also captures the number of CSP installation around the world. The total capacity of CSP developed between the year 1985 and 1991 was only 345MW and this was done in California. CSP technology over the last decade has seen a huge boost and today there are several CSP being developed over the last few years because of reduced investment cost and leveled cost of electricity generation. The leading producer of electricity from CSP currently is Spain [46]. Many projects on CSP found in the United States are either under construction or even in the planning phase. The increased interest in CSP technology has also contributed to the recent commencement of other CSP projects around the globe. Fig. 9 shows a newly added CPS and the exact characteristics of each of these types of CSP are well defined below.

3.1 Parabolic Trough (PT).

Radiations are directed onto heat absorbers positioned on a focal line of the parabolic mirror. Coating of receivers is done mainly to increase the absorption rate of the receivers and also to reduce re – radiation of the infrared. Heat loss due to convection is curbed by positioning the receivers in a glass. Salt which is the heat transfer liquid is used for the removal of the thermal energy and this is sent to a generator to generate a superheated steam [34]. The steam at higher temperature drives the turbine and produces electricity. The water then flows back to the heat condensers once they are cooled leading to condensation of the water. Nearly 850MW is the total installed capacity for parabolic troughs. Most parabolic troughs are with the range of 14 – 80 MW and can be found in Spain and the United States. Parabolic troughs utilizes the older method commercially accepted as the best CSP technology, it also has an efficiency of nearly 15%, the system is modular, good storage capability and good investment cost and cheap to operate are some well know advantages of PT CSP. They have high thermal losses and the mode of heat transfer is considered not to be that ideal. PTs also have lengthy pipes between the array and the steam generating plants and these are considered as some demerits of using this technology.3.1.1

Linear freshnel Reflectors.

The linear freshnel reflectors operates just like the parabolic trough but the linear freshnel reflectors comes with a long flat and curved mirror connected in series. A receiver is placed at a fixed position to absorb the sun radiation after the mirror fixed at varying angles directs the rays from the sun to the receiver [34]. The receiver is designed to be position above the mirror field. A tracking system is attached to the mirrors in order to absorb the maximum amount of sun radiation and also aid in the optimization of the entire system. The focal length of the linear freshnel reflectors may be distorted because of astigmatism which is not the case for parabolic troughs. With the aid of secondary reflectors, solar radiation that may not fall on the mirror is redirected to the expected location. The compact linear freshnel reflectors, is one of the latest states of the art technology being utilized in CSP. It comprises of 2 equivalent receivers for every mirror to reduce the acres of land needed for the installation and also uses PT to generate the expected output. The world currently can only boast of 3 linear freshnel reflector plants which was established back in 2008. These plants are located at Murica, South Wales, USA and California. The maximum capacity for each of the plants are 5MW, 4MW and 1.4MW. The materials for the linear freshnel reflectors are easy to find on the market and the capital cost for installing LFR plants are cheap compared to PTs, the steam itself can produce steam due to the fact that water is being used as the liquid for the heat transfer process, Hybrid operations can also be executed and the overall losses because of heat transfer is less compared to the others. The overall efficiency for converting solar to electricity is only 8 – 10% which is far lesser than the parabolic trough, combination with thermal storage makes is more complex and these are all considered as some possible disadvantages of using the LFR.

3.1.2 Parabolic dish collector

Solar dish collectors are a concentrated solar power technology which involves solar radiations being directed to a focal point. Tracking of the sun is done by the dish as well as the receiver and this occurs due to their movement in the tandem. Parabolic dish collectors therefore do not need heat transfer liquid and cooling water simply because of their design and this phenomenon leads to a higher heat to electricity conversion ratio. It is also considered as the future provided it can be produced on a larger scale. This will therefore create some competition with existing technology (solar thermal systems). Today Europe has 10kW systems whiles the United States equally have some few projects running but still at the developing stages. Australia on the other hand has 100 MW project being constructed. There is over 30% conversion efficiency when this technology is utilized, making them more advantageous compared to the others. It also does not require any cooling systems, it is very useful for stand – alone and remote projects, the system is modular, there is no restriction irrespective of the nature of the terrain (Flat terrain), manufacturing process is simple, the use of existing parts makes the mass production of the concept very possible. All these are some advantages of relying on this technology, but it has its setbacks as well [34]. There are no large-scale commercial plants, there is also no investigation to prove the investment, performance and the operational cost of this technology and very difficult when the concept is to work in parallel to a grid connection.

3.1.3 Solar Towers (ST)

Solar Towers (ST) involves using computer supported mirrors, called as heliostat, to track the sun path separately on two axes. A single receiver absorbs the solar energy radiated from the mirrors. The receiver is fixed at the apex of the tower where there is the running of a thermodynamic cycle using heat and generating electricity. Comparatively there is more concentration of solar radiation using the solar towers to using concentrated solar powers technologies. The transfer fluid used is water stream, synthetic oil and molten salts. It functions even at higher temperatures but solar towers on a normal day has its operating temperature between 250 – 1000^{o}C and this temperature range is subject to the design of the receiver and even the working fluid. Solar towers today are almost at the commercialization stage [47]. Again, the earliest type of solar towers was initially built in California, United States between the 1980s and the 1990s. Currently Israel, Germany and Spain are championing several solar tower related projects after the initial projects in the United States were decommissioned years ago. The operating temperature of ST makes them more advantageous compared to the others as this makes them highly efficient, they are also good for dry cooling compared to PT and its installation process especially on hilly areas is easy but its main setbacks are their lack of their availability commercially, investment cost and their performance has also not been verified yet [48]. Table 2 and Table 3 shows some CSP projects being installed and their expected completion dates.

3.2 Obstacles impeding the advancement of CSP energy

It is projected that the entire CSP capacity will increase to 30 GW in USA and 23 GW in Africa in 2020. It is anticipated that these projections might go up to 337 GW by 2030. There are several factors that must be critically considered if concentrated solar power technology is to compete with existing concepts. Some of these critical issues can be captured under the different categories such as storage, power, cooling as well as transmitting the heat and electricity. Another major factor is related the high capital cost needed to initiate CSP energy harvesting project [49 – 52]. The parabolic troughs and the linear freshnel reflectors must be exploited properly. The thick glass sheet used in the aforementioned technologies can be replaced by a less expensive material. Using cheap heat transfer fluids should also help reduceing the overall cost of this technology. The efficiency of CSP can be improved by using a direct steam generator, often used for parabolic trough, to increase the working temperature. The high demand of land for the different CSP technology projects make them less attractive to end users. This is because high intensity reflectors are required to direct the sun rays to the receivers and these receivers are normally built meters away from the reflectors. Additionally, the CSP plant is normally located on a far-enough distance from the end users and this may lead to high distribution losses. Instances where the solar radiations are diffused, the performance of the CSP will reduce drastically.

3.3 Future prospects of Concentrated Solar Photovoltaics (CSPs)

With the consumption of fossil-based product increasing every day, the drive to reduced carbon emissions globally continue remain a critical issue in today's world. Nearly 40 – 43% of the world's energy demand is obtained from fossil fuels. One of the non-conventional energy systems as explained earlier is the CSP [53,54]. Some researchers considers this technology as the future of energy generation and for this it has received increased research efforts in the recent years. R&D activities financed by the International Energy Agency (IEA) on concentrating solar technologies like the SolarPACES have helped reduce the cost of CSPs (Solar thermal plants) as well as their performance. There have been tremendous improvements in CSPs pilot plants as well as other large scale testing projects. These advances, along with cost reductions made possible by increasing mass production rates and construction of a succession of power plants, have made CSP systems the lowest-cost solar energy in the world and promise cost competitiveness with fossil-fuel plants in the future [55]. As explained earlier, the trough system utilizes linear parabolic concentrators to direct sun radiation to a receiver along the focal line of the collector. Due to their thermal characteristics, the trough system can be hybridized or operated using fossil fuel and solar energy. Hybridization will increase the CSP technology in terms of increasing their availability and dispatchability. This in turn will reduce the cost [56].

In Southern California , the parabolic trough connected to the grid since 1980s is considered the most matured types of CSP technology in the US. The performance of these plants have increase over their operational lifetime [57]. The Kramer junction site where another parabolic trough is located, achieved a 30% reduction in their operation and maintenance (O&M) costs. The reduction is achieved by improving the design of the collector and enhancing the O&M procedures [58]. Also, there has been advancements in the production techniques for the trough. Companies like SOLEL in Israel has improved the absorber tubes and the Flabeg. A further reduce in the cost of the technology can be attained by designing a cost-effective collector field and more durable receivers and collector structures [59]. Further advancements are also required in terms of the operation and maintenance of the system. The possibility of replacing the synthetic oil with water must also critically be investigated as a way of reducing the cost of the system. Further advanced hybrid designs must be considered. For instance, solar/fossil hybrid design integrated with a combined cycle power plants will effectively improve their performance. There should also be more research geared towards concentrating solar energy on linear receivers like the linear Fresnel reflector that uses a flat mirror located close to the ground in Australia [60]. This technological advancement reduces the concentrator wind loads but increases the packing density. This therefore reduces the overall cost of the CSP system. These investigations are being carried out in German/Spanish Direct Solar Steam Project. The projects goal is to reduce the cost of the energy produced by this technology by 26%. Plataforma Solar de Almeria is also conducting series of investigations into the receiver configurations as well as the reflectors for trough applications. For power tower plants, improvements in the heliostat field due to better optical properties will be the future for this technology [61]. Again, reducing the cost of the structures during the installation process will further decrease the cost of this technology. Some modification on the heliostat design can include increasing the area of the heliostat. This investigation is being carried out by Inabensa and Ghersa in Spain. Improvements in the system integration by reducing parasitic loads, optimization of startup procedures as well as better control strategies will further increase the overall performance of the system [62]. A novel technique used in Israel is the application of a second reflector on the tower top to direct solar energy to the ground level for collection at higher temperature for their application in a gas turbine [63]. Integrating a high temperature solar system to a gas turbine will increase the efficiency of the gas turbine compared to steam turbine applications. There is also the advantage of a faster start up times, lower installation and operating expenses [63].

4.0 Enhanced Geothermal Energy Systems (EGES)

This type of energy is stored in the earth. It is believed that geothermal energy is formed from the decay of material radioactively [63-65]. Geothermal gradient is the difference in temperature between the surface of the earth and the core of the earth. Today geothermal energy is in good competition with the other energy generation medium [66]. Fig. 10. Shows the capital cost and payback for traditional renewable energy generation mediums. Regional and local tectonics actively contribute to the future sustainability of these natural reservoirs. These critical factors make geothermal energy techniques location dependent as only places with good natural reservoirs can have these energy generation media being used. Today, researchers have developed a new technology which is an upgrade of geothermal energy called enhanced geothermal systems (EGS) [67]. This technology is also called engineered geothermal energy (EGE). This implies that the approach can be suitable for all other areas irrespective of the possibilities of natural reservoirs or the opposite. The lifetime for most EGS is higher than traditional geothermal energy techniques. Again, there is also an increase in productivity using EGS and the location where the projected can be sited is limited to any specific conditions. The resources can be expanded and there is also some flexibility in the sizing of the project. Finally, EGS is environmentally friendlier than the conventional geothermal energy generation mediums [68-70]. There are several parameters involved in other to keep EGS in an operational mode. These parameters are the reservoir, the conditions of the environment, well drilling as well as completion of the well. Drilling to an appropriate depth where the temperature of the rock is enough to justify the investments a key stage in thermal energy generation. Developing EGS reservoir is the first stage in developing a power plant using enhanced geothermal system at an appropriate location. Several other stages are required to generate geothermal energy and this has been captured in a report [71,72]. He explained five main stages in the geothermal energy generation process.

A well is built into a heated basement rock which is less permeable with less fluid content as shown in Fig. 11. This basically serves as the point of injection. For existing fractures to reopen, water with high pressure is pumped into these openings. The water is injected continuously even when existing fractures are opened, and this sometimes leads to more fracture openings precisely at the hot basement rock. The fracture system created is intersected with a drilled well and the main purpose is for the water to easily be in circulation. The research into enhancing the performance of geothermal energy has been conducted by several researchers around the world [73]. Some areas that has been critically investigated has to do with the geothermal resource base assessment, recoverable EGS estimates, in depth research on EGS technologies and the present performances, designing of subsurface systems, drilling technology economics, topics surrounding the conversion of energy using enhanced geothermal systems, the effect of this technology on the environment, analysis of enhanced geothermal systems and their sustainability [74]. There are several benefits involved in the usage of EGS, but this viable technology is not evenly distributed in terms of its resource base. For places considered as high tectonic regions, for a depth of 6km or less, almost 150^{o}C temperature is expected but this is not dependent on the resources in that specific environs [75 - 77]. In areas where flow of heat is extremely high especially in high temperature regions, thermal conductivity is low and this makes the region very suitable for this technology. Due to local limitations, even areas considered as being favorable may not be able to have all the EGS potential being exploited. Some of these limitations are main roads, urban communities, utility corridors, government protected reserves and national monuments. Today Japan, German, France and UK are all championing projects in this area. The completion of the project gave rise to others like the Roemanowes project. The main object for this project was to expand the concept of building a storage site in a rock. The experimental research was conducted in 1975 in the United Kingdom. Similar experiments were equally performed in Japan [78]. Systems used in the energy conversion for enhanced geothermal systems is done using traditional geothermal systems with some little changes being done. Challenges relating to the usage of enhanced geothermal fluids, leads to adoption of ideas from fossil fuel energy conversion systems. Using carbon dioxide as the transfer medium for the heat in enhanced geothermal systems has its own setbacks. Some investigations have been conducted to examine the impact of using this approach [79]. Geothermal power projects have severe impact on the environment. Irrespective of these implications on the environment, they are still considered as being more environmentally friendly compared to fossil fuel as well as nuclear power projects [80]. Some considerations must be carefully examined before the commencement of any enhanced geothermal system related project. This is basically related to the possibility of ground water being contaminated, induced seismicity and land subsidence. There are other related issues like noise pollution and air pollution that must equally be well evaluated. Differences between enhanced geothermal systems and hydrothermal systems are few. The enhanced geothermal system is designed to support the mining of heat and stimulation of a reservoir from a small area of rocks at specific depths to extract thermal energy [80]. The reservoir has the same characteristics to hydrothermal systems. There are several systems used in the conversion of geothermal energy to power. The binary recuperators, single flash and triple expansions are some major energy conversion systems used in enhanced geothermal systems [81].

4.1 Obstacles impeding the advancement of Enhanced Geothermal Systems.

Some assumptions are made during the design process for all enhanced geothermal systems. These assumptions require an in-depth research investigation if this technology is to be used on a larger scale aside the high initial capital cost need in the establishment and running of the project. The other related issue has to do with the sustainability of the reservoir. According to an investigation conducted, fluids flowing with a temperature of 200^{o}C at 80kg/s is required for enhanced geothermal system plant even though all Enhanced geothermal systems currently under investigations are not even able to have a mass flow rate of 25kg/s. There are currently no experimental research conducted to determine the performance of an enhanced geothermal reservoir capable of being operated at a commercial level at their specific locations having different properties geographically. A good investment in research and development will make enhanced geothermal systems a good competitor with other energy generation mediums as especially with it being environmentally friendly. The competition in effect will reduce the high dependency on fossil fuels and other energy generation mediums that are very harmful to the environment. EGS are highly sustainable but they can sometimes lead to earthquakes and landslides especially where the wells or reservoirs are to be sited. Enhanced geothermal technology also have the tendency of reducing the quality of water bodies and some little air pollution in instances where there is poor maintenance of the plants.

4.2. Future prospects of Enhanced geothermal energy

There is urgent need for more R &D programmes on the exploration data, technologies used for drilling as well as the operation and maintenance of the reservoir. To reduce the cost of enhanced geothermal energy, technologies used in harnessing these types of energy generation medium must be critically evaluated. Some of these technologies include temperature hardened submersible pumps, zonal isolation tools, monitoring and logging tools and coupled models to determine reservoir development [82]. Development of the techniques used in the drilling process for harnessing enhanced geothermal energy would contribute in reducing the drilling cost as well as the electricity produced via this medium. An integrated energy conversion system like solar geothermal hybrid should be encouraged in order to enhance the quality of geothermal energy and increase the efficiency as well as the capacity of the energy system. Cascade technology for enhanced geothermal systems must be encouraged to ensure sustainable exploitation and usage of geothermal energy [83]. Other recommended ways of improving the advancement of enhanced geothermal energy is their application in water desalination, geothermal plants with carbon capture and storage [84 – 86], geothermal water usage for spas and health tourism [87], synergy of geothermal energy exploitation using deep oil and gas systems [88,89] and coupled with district heating systems [90,91]. Optimization of enhanced geothermal energy must be economically viable. Other criteria like the thermodynamic efficiency and the life cycle environmental impact must all be carefully evaluated [92 – 94]. These are some of the key factors that will lead to the easy commercialization of this novel energy generation medium. The cost of energy production still remains a challenge to businesses as well as the entire community. Enhanced geothermal energy can be produced domestically, therefore ensuring security for energy supply for domestic applications [95]. Enhanced geothermal energy is not directly linked to any extra cost like land degradation, pollution, animal and plants destruction etc. The advantages of geothermal energy are enormous. It can provide job security and revenue for rural communities [96 - 99]. Again, most geothermal communities currently support in community development projects and programmes. Deep wells typically exhibit high uncertainty on well costs, which are controlled by the probability distributions of key variables. The decision aids for tunneling (DAT) programme was developed to explore the uncertainty of well costs as a function of a fixed material cost, hourly cost and the time needed for an enhanced geothermal project [100]. Some researchers have developed a correlation to determine the economic feasibility and risk of an enhanced geothermal energy project between 2400 – 4600m geothermal wells [101 - 103].

5. Conclusion

Enhanced Geothermal Energy (E and concentrated solar photovoltaics are emerging types of renewable energy technologies that are still undergoing significant developments. Factors impeding their commercialization was critically reviewed and discussed. Solutions to the major challenges were also presented. Furthermore, the prospects of such interesting energy generation mediums were also ascertained. In order to push the borders of these technologies and achieving further advancements, there is an urgent need for more governmental support in terms of research, technological development and demonstration projects. Major investments are needed to properly develop and market both technologies and this can only be achieve through developing long-term regulatory policies which can only be provided by legislative and governmental support.

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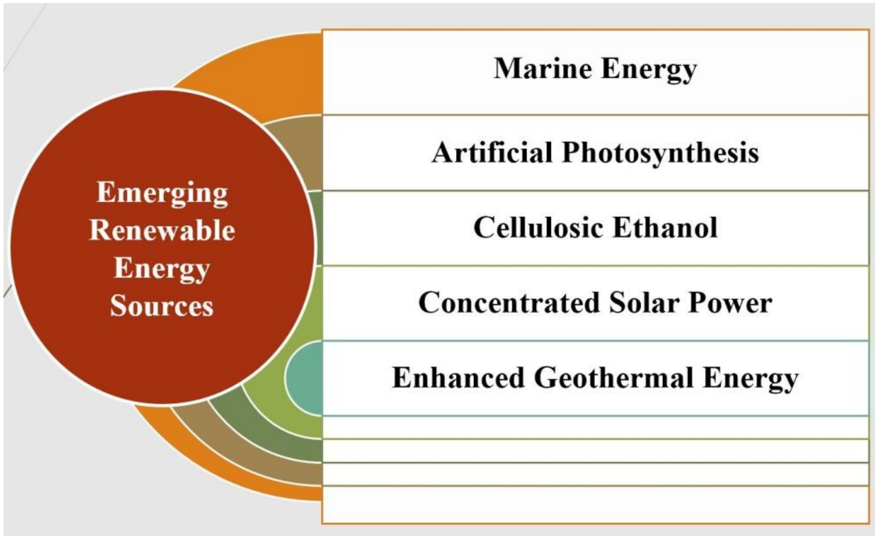


Fig. 1: Emerging renewable energy generation medium

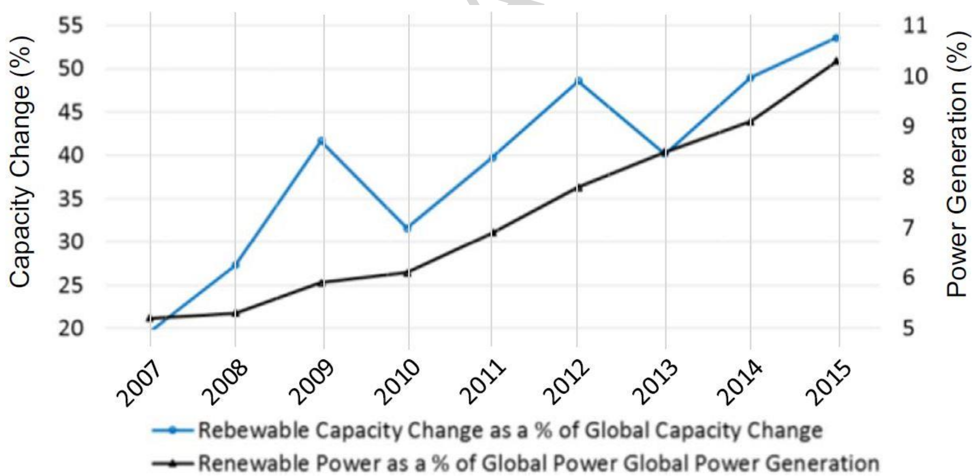


Fig. 2: Global renewable energy capacity [18].

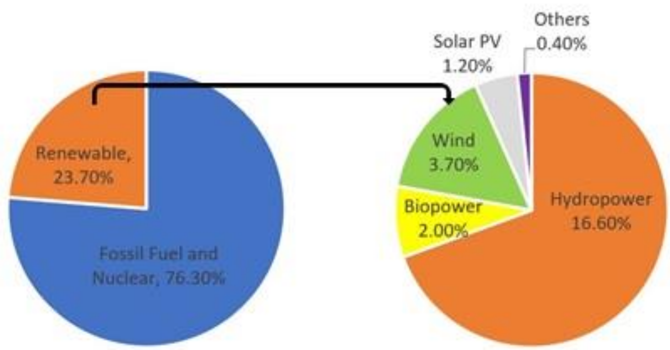


Fig. 3: Global Energy demand [Permission to reproduce from 16]

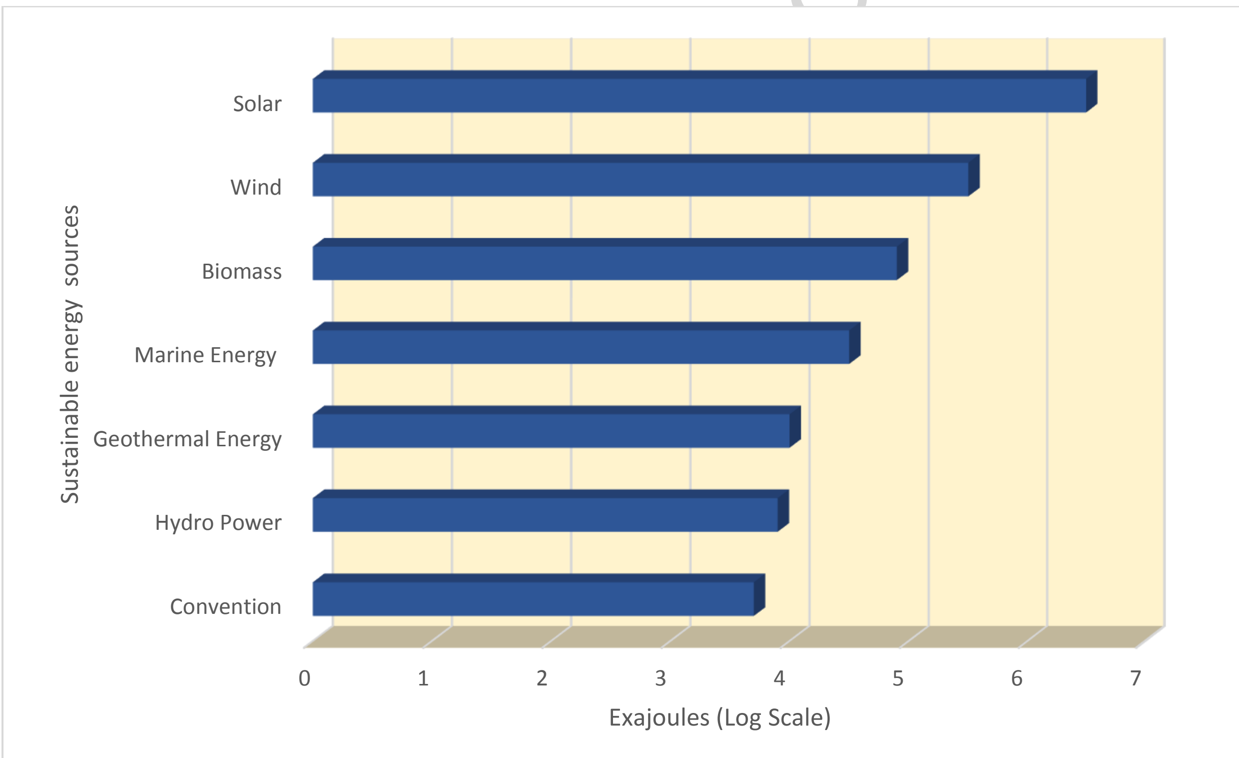


Fig. 4: Sustainable energy sources [Permission to reproduce from 16, 34]

Fig. 5: Concentrated solar plant built near Tecate Mexico [Permission to reproduce from 32]

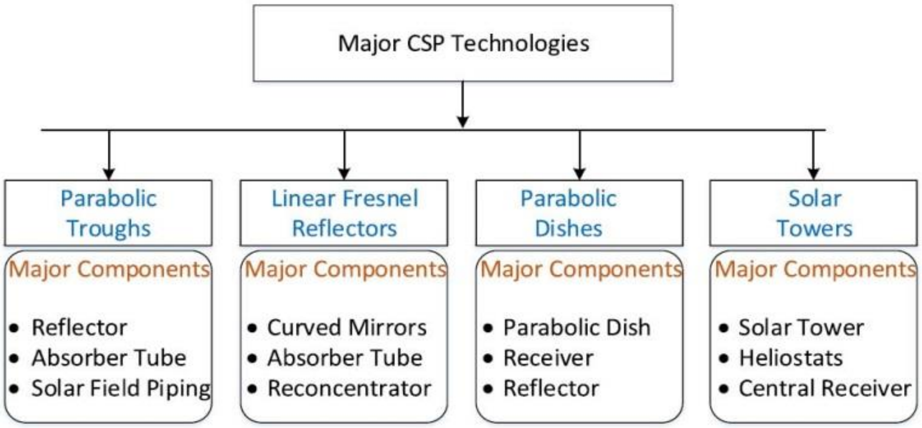


Fig. 6: Concentrated solar photovoltaic types [Permission to reproduce from 34]

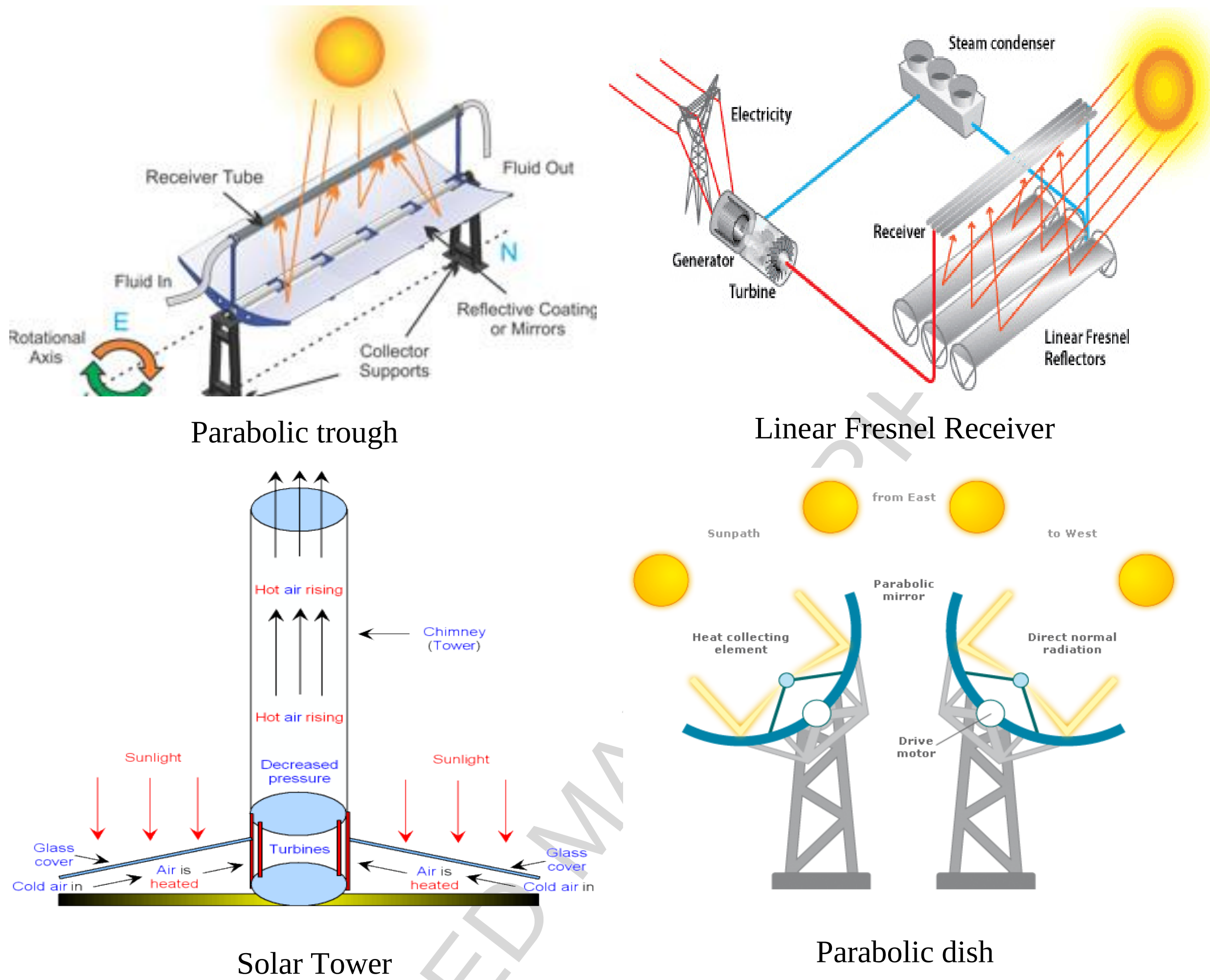


Fig. 7: Concentrated solar photovoltaic technology currently being used [Permission to reproduce from 41].

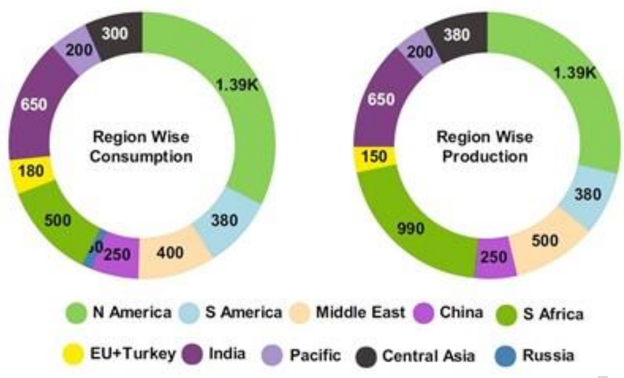


Fig. 8: Projections made for 2050 on regional energy generated via CSP technology [Permission to reproduce from 34].

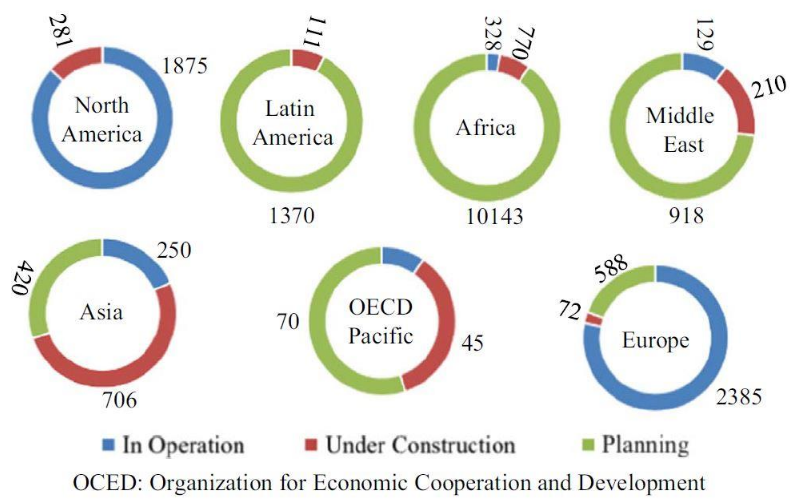


Fig. 9: Concentrated solar power capacities for various regions in the world in 2012 [Permission to reproduce from 34].

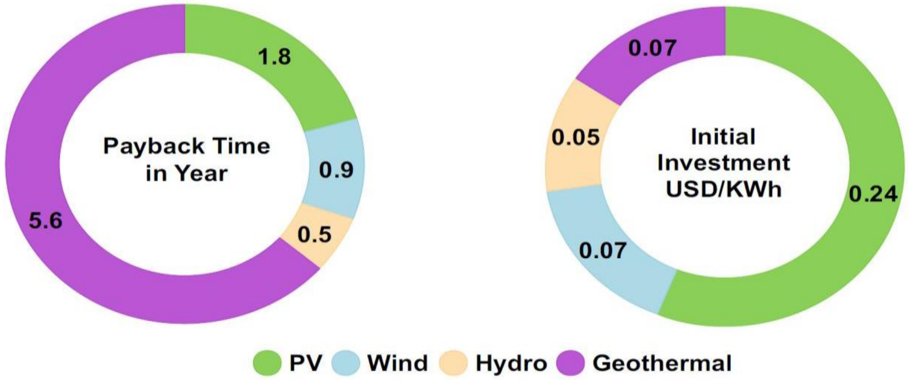


Fig. 10: Payback period and capital cost for renewable energy generation mediums [Permission to reproduce from 34]

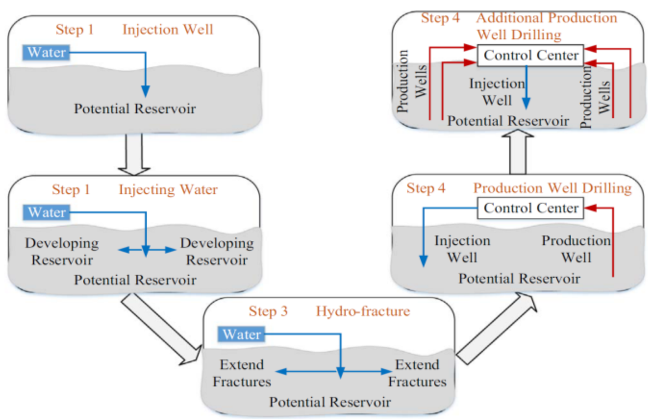


Fig. 11: Stages for Geothermal energy system development [Permission to reproduce from 34]

Table 1: The projected future of renewable energy sources by 2050 [34]

Types	Medium	Measured value	Year 2013/14	Scenario (2015 - 2017) projections	Renewable Energy roadmap by 2050
Electricity	Hydro power Wind Solar PV Bioenergy Geothermal Ocean Battery Storage	GW GW GW GW GW GW GWh	1170 370 175 95 12 0.5 130	1830 1070 780 250 42 2 1580	1995 1990 1760 430 92 7 4000
Transport	Electrical	Million	0.8	60	160
	Vehicles	Vehicles			
	2/3 Wheelers	Million	200	500	900
		Vehicles			
	Bio - liquids	Billion	130	251	499
		Liters			
	methane	B/m^3	0.02	0.29	0.89
Commercial purposes (Coperations)	Bio – energy heat	Exajoules per year	0.8	10	16.9
	thermal		0.1	8	105
	thermal	Million m^2	0.99	50	659
	Geothermal	Exajoules per year	0.019	0.048	0.39
	thermal Pump	M	0.2	3	18
		units			

Buildings	Bioenergy Bioenergy Bioenergy Heat Solar thermal Geothermal Heat Pumps	Exajoules per year EJ/yr Million m^2 EJ/yr Million m^2	35 2.5 4 534 0.3 4	21 4 10 2020 0.7 32	0 13 15 3230 0.8 42

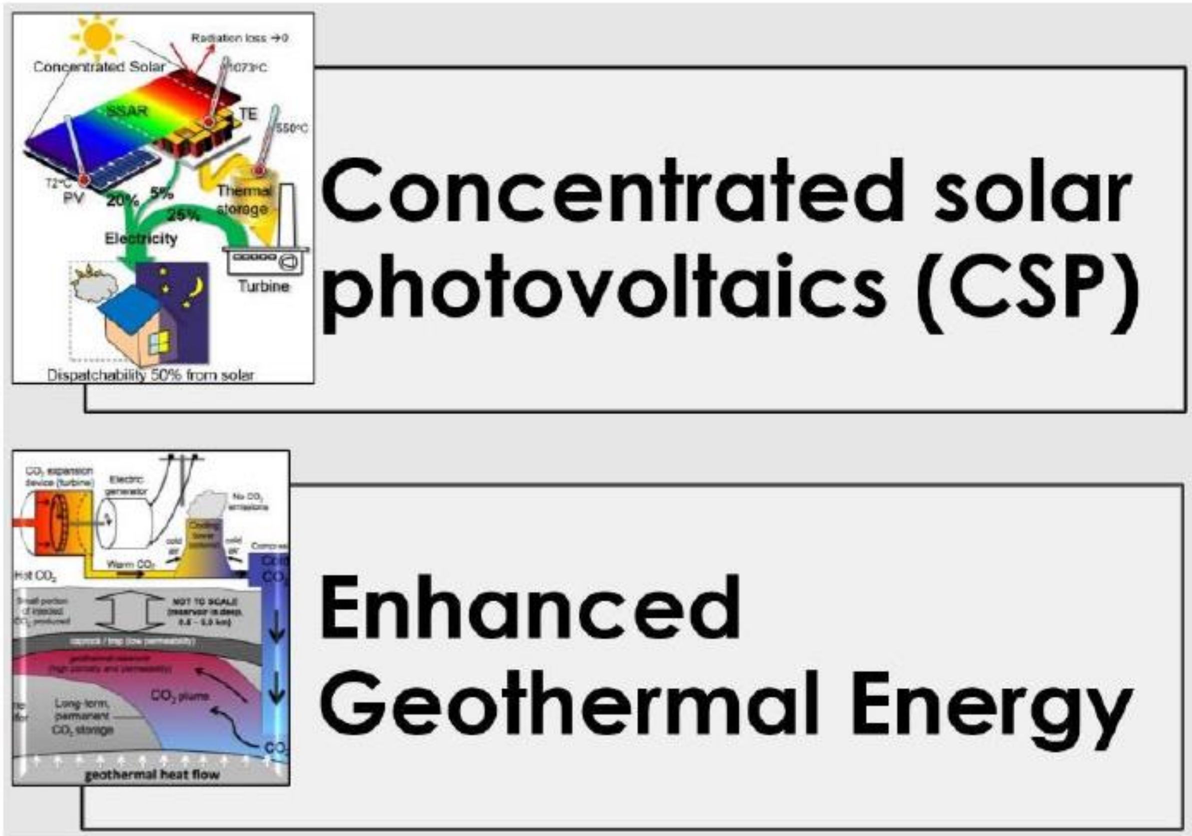
Table 2: Some CSP projects around the world [34].

Project	Developer	Technology	Heat Transfer	Capacity (MWe)	Storage capacity (Hours)	Date of Completion
SEGS I – IX	Luz	Parabolic trough	Oil	354	0	1986 – 1991
Nevada Solar One	Acciona	Parabolic trough	Oil	64	0	2007
Martin	Florida power and light	Parabolic trough	Oil	75	0	2010
Solana	Abengoa	Parabolic trough	Oil	250	0	2013
Ivanpah	Bright source energy	Solar Tower	stream	390	0	2014
Mojave	Abengoa	Parabolic trough	Oil	250	0	2014
Genesis	NextEra	Parabolic trough	Oil	250	0	2014
Crescent Dunes	SolarReserve	Solar Tower	Molten salt	110	0	2015

Table 3: CSP project with storage currently being developed around the world [34].

Project	Country	MWe	Storage capacity (Hours)	Power Purchase agreement price (PPA$/kW	Status	Completion date
Crescent Dunes	U.S.	110	10	13.7	operation	2015
Noor III	Morocco	150	7.5	16.3	construction	2017
Redstone	South Africa	100	12	12.5	Development	2018
DEWA CSP Project Phase I	United Arab Emirates	200	12	8.0	Planning	2021
Copiapo	Chile	240	14	6.3	Planning	-

Graphical abstract



Highlights

1. Technologies for harnessing Concentrated Solar Photovoltaics and Enhanced Geothermal Energy are thoroughly discussed.
2. Challenges impeding the advancement of these energy generation mediums are also presented.
3. The future prospects of Concentrated Solar Photovoltaics and Enhanced Geothermal Energy are captured in this investigation.
4. Some recommendations for easy commercialization of these technologies are also reported.